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AUTOTHERMAL THERMOPHILIC AEROBIC DIGESTION IN
THE FEDERAL REPUBLIC OF GERMANY

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16. ABSTRACT The status of Autothermal Thermophilic Aerobic Digestion (ATAD) of Wastewater Sludges in the Federal Republic of Germany (FRG) was evaluated via site visits to operating facilities. In the FRG, three variations of ATAD systems have been constructed on a full scale. These include systems marketed by Fuchs Gas and Wassertechnik GmbH and Co., Theime Umwel Hecknik GmbH, and Babcock (Deutsche Babcock Anlagen Aktiengesellschaft). Fuchs is the leading supplier of these systems with approximately 13 of the 17 facilities in FRG and Switzerland. The ATAD process in the FRG is required to meet a limitation of 100 enterobacter/ml in the final sludge product. ATAD maintains a status of approval by the Federal Government (FRG) as a process that is capable of producing a pasturized (hygienic) sludge. The process appears to be simple to operate and cost effective compared to existing digestion technologies.		
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INTRODUCTION AND BACKGROUND

The Autothermal Thermophilic Aerobic Digestion system is an aerobic digestion process that operates within a thermophilic temperature range (40°C to 80°C) without the introduction of supplemental heat.

The potential for conducting autothermal thermophilic aerobic digestion (ATAD) of wastewater sludges has been known for some time. In 1969, Kambhu and Andrews¹ reported the results from computer simulations which showed that ATAD could be self-sustaining with respect to temperature. In simulations with air aeration, it was predicted (Andrews and Kambhu²) that sludge temperatures could increase by more than 33°C and that the percentage of volatile solids destroyed would be greater than 40% at residence times greater than 7.5 days.

Much of the early experimental work on which full-scale ATAD systems have been based was performed by Popel and coworkers.^{3,4,5,6} The process was demonstrated both with animal manure and sludge having high concentrations (10-60 kg/cu m) of organic solids and using the "Umwalzbelufter" developed by Fuchs to provide proper aeration. Reactor temperatures of 50°C were obtained even at low ambient temperatures.

The empirical operating characteristics of this aerator type (self-aspirating aerator) were reported in the late 1960's⁷. The aerator and several comparable designs were successfully marketed and implemented for industrial and agricultural waste treatment in the US by the DeLaval Company in a patented process called the LIQOM (from liquid compositing) system. Studies on dairy, beef and swine wastes in the US indicated that autoheating to thermophilic temperatures was possible.

In 1971, substantial increases in temperature were inadvertently obtained at the Hamilton, OH wastewater treatment plant when the covered digesters were converted to aerobic digesters.⁸ Temperatures of 38°C were obtained when the 4% feed solids concentration was fed to the digester at a rate of 2 kg/cu m/day. Insufficient air was available to maintain a positive DO concentration and odors were present.

Other ATAD studies were conducted in the early to mid 1970's in the US with high purity oxygen (Smith et al.,⁹ Matsch and Drnevich¹⁰). Union Carbide was reported to have been working on ATAD systems utilizing high purity oxygen since 1972. Studies at the Speedway, IN treatment plant indicated that substantial increases in temperature were possible although thermophilic conditions were not attained. Pilot plant studies at Tonawanda, NY on both single and two-stage digestion systems were conducted under autothermal thermophilic conditions. Based on these studies, it was concluded that an ATAD system operating at a 5 day HRT could achieve volatile solids destructions equivalent to a conventional system at a 15 to 20 day HRT. Nitrification was observed to be inhibited under thermophilic conditions. It was also concluded that reductions in pathogenic organisms to less than detectable levels could be achieved when the temperature of the sludge was maintained at 50°C or greater for 5 or more hours. Similar reductions could be achieved at temperatures as low as 45°C with longer residence times. Sludge produced from an ATAD system was shown to dewater as well as an anaerobically digested sludge.

The most extensive study of ATAD using air aeration in the US was conducted at Binghamton, NY in 1977 and 1978 (Jewell et al.,¹¹ Jewell and Kabrick¹²). A combined primary and waste activated sludge feed between 3 to 6% TS was fed to a single reactor operated with a liquid volume of 28.4 cu m (1000 gal). The design was

based on the system marketed in this country by DeLaval Inc. Both a Midland-Prings aerator and a DeLaval centri-rator aerator were studied. Start up always occurred rapidly regardless of air and sludge temperatures and following start up, reactor temperatures were always in the thermophilic zone ($> 43^{\circ}\text{C}$) and often above 50°C . Oxygen transfer efficiencies always exceeded 12% and the highest values approached 23%. There was no nitrification but there was some $\text{NH}_3\text{-N}$ loss due to stripping. A high degree of pathogen control with respect to bacteria, viruses and parasites was reported. A significant deterioration in the dewaterability of the treated sludge was observed. Practical operation and maintenance problems were found to be minimal. ATAD was also felt to be more economical than aerobic or anaerobic digestion facilities at equal solids conversion efficiencies.

Based on the results reported by Jewell et al., Camp Dresser and McKee¹² performed an economic analysis which compared ATAD with conventional aerobic and anaerobic digestion at 1, 10 and 100 MGD (sludge handling costs before and after digestion were not included). At the 1 MGD sizing, unit digestion costs in dollars per dry ton (\$/ton) of sludge processed, were estimated to be 160, 260, and 220 for ATAD, aerobic digestion and anaerobic digestion respectively. At 10 MGD and beyond, anaerobic digestion was projected to be the most cost effective alternative. (The value of sludge pasteurization by the ATAD process was not considered.)

More recent research reported by Wolinski and Bruce¹³ indicated that the ATAD process could compete with anaerobic digestion if the aeration/mixing power requirements are minimized.

PURPOSE AND METHODS OF ASSESSMENT

In support of the Innovative and Alternative Technology Program, the Environmental Protection Agency retained Roy F. Weston, Inc. (WESTON) to update developments in ATAD technology utilizing air aeration. It soon became apparent that there was very little interest in this technology in the United States¹⁴. This contrasted sharply with information available from the Federal Republic of Germany (FRG) where it was reported¹⁵ that the process had been utilized for more than ten years. It was further indicated that the aeration devices had been substantially modified and improved compared to the aerators utilized by Jewell et al. The aerators presently utilized by Fuchs (an aerator manufacturer in FRG) were claimed to operate at 95 w/cu m of reactor volume which is about half the energy input observed by Jewell et al. for best operation. Also it was reported that ATAD sludges dewater just as well as anaerobically digested sludge in centrifuges or belt presses. To evaluate these and other claims, the focus of the ATAD technology assessment was shifted to an evaluation of those systems presently in operation in Europe.

Dr. Egon Keller of ECOSYSTEMS in the FRG compiled available information from the academic community, operating plants and manufacturers. Following review of information received from FRG by WESTON and EPA, a first hand evaluation of operating facilities was conducted by WESTON. The evaluation was supplemented through discussions with operating personnel, design engineers, researcher and manufacturers. The FRG ATAD assessment primarily reflects the findings of WESTON in association with support from Dr. Egon Keller.

PROCESS DISCUSSION

Detailed discussions of the heat and mass balance equations necessary for describing ATAD system operation are available (Andrews and Kambhu,² Kambhu and Andrews,¹ Jewell et al.)⁷ and will not be repeated here. The same basic analytical approach has also been utilized in Germany¹⁶. The various inputs, outputs and heat production items to be included in a heat balance are illustrated in Figure 1. An efficient aeration device is essential if the latent heat loss in the water vapor is to be held at an acceptable level. Systems currently in operation in Europe do not use heat exchange between reactor feed and effluent to warm the incoming sludge. Heat exchange is occasionally practiced for waste heat recovery. Biological heat production is, by far, the largest heat source with typical heat production values of 6100 to 6300 BTU/lb O₂ utilized^{2,7,17} being reported or assumed. Although variable, carbonaceous oxygen requirements are often considered to be 1.42 lb O₂/lb VSS oxidized. Thermophilic temperatures prevent biological nitrification which results in a substantial reduction in O₂ demand compared to conventional aerobic digestion systems. The rate of digestion is commonly described by first order kinetics with the rate coefficient increasing up to approximately 60°C¹⁸. Feed sludge biodegradable solids concentration and temperature, biological reaction rates and efficiency of the aeration device are key components in process analysis.

Significant advances have been made in the optimization and adaptation of the ATAD technology during the past 15 years. Much of the experimental work on which the present full-scale ATAD systems have been based was performed by Dr. Klaus Breitenbucher while at the University of Hohenheim. Much of this work was based upon the operation of a full-scale ATAD plant at Gemmingen, FRG¹⁶. To date, the process utilization in Europe has been primarily in West Germany with a little employment in Switzerland.

DESIGN

In the FRG, three variations of thermophilic aerobic digestion systems have been constructed on a full-scale. These include systems marketed by:

- o Fuchs Gas and Wassertechnik GmbH & Co. K.G.
- o Thieme UmwelHecknik GmbH
- o Babcock (Deutsche Babcock Analgen Aktiengesellschaft)

Of these manufacturers, Fuchs is the leading supplier of these systems with approximately 13 of the 17 facilities in the FRG and Switzerland (per the manufacturer). An additional 5 facilities are under design for the FRG and additional orders are anticipated in Switzerland. Thieme has two full-scale systems operating in industrial applications in the FRG. Limited operating data are available from these facilities. Babcock has one full-scale facility located in Aidlingen, FRG.

Due to the number of systems installed and the early research and development work performed by Dr. Breitenbucher, the ATAD systems that were visited were all systems supplied by Fuchs. Thieme and Babcock installations were discussed with manufacturer's representatives and data were solicited while in Germany.

There are significant differences among the actual operating ATAD systems. Typical design parameters for each of the three versions of the process are summarized in Table 1 and are discussed below:

Figure 1

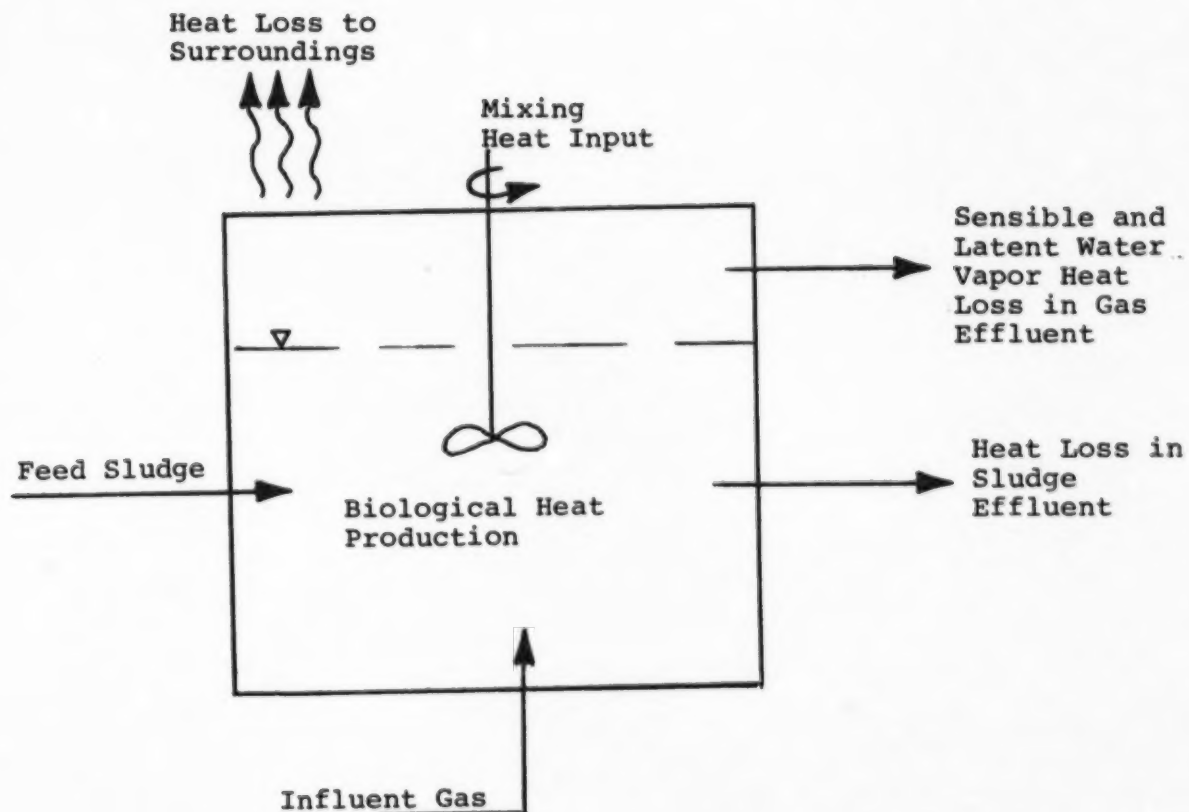


Figure 1: Heat balance schematic of a thermophilic aerobic digester.

TABLE 1
SUMMARY OF DESIGN PARAMETERS

DESIGN PARAMETER	MANUFACTURERS		
	FUCHS	THIEME	BABCOCK
Sludge Feed Concentration, percent (%)	3-5	10-12	3-6
Hydraulic Detention Time, Days	5-6	6-7	3-6
Number of Reactors	2	2	1
Sludge Storage Capacity, Days	20	70	-
Operating Strategy	Batch	Batch	Semi Continuous
Aeration ₃ Requirement, KWH/M ³ of sludge throughput	12-14	-	12-17
Mixing ₃ Requirements, W/M ³ reactor volume	86	200-300	-

o Fuchs

The Fuchs ATAD system employs two enclosed and insulated sludge digestion reactors which are operated in series. Typical designs require pre-thickening and post sludge storage/thickening prior to land application. A typical Fuchs system is illustrated in Figure 2. The pre ATAD sludge thickening is sometimes accomplished jointly with primary solids removal as is the case at two facilities reviewed in Germany. At those facilities, primary solids removal is accomplished by dissolved air flotation (which is a frequent practice in Europe). Waste activated sludge is pumped to the primary DAF for thickening and removal with the primary sludge. This sludge is then delivered to the ATAD system.

The feed solids concentration of 3 to 5 percent has been established by Fuchs to limit excessive reactor cooling at concentrations below 3 percent and to limit excessive foaming in the reactors which reportedly occurs at concentrations greater than 5 percent.

The hydraulic detention time is established at 5 to 6 days (2.5 to 3 days per reactor) to satisfy the process requirements of 40-percent destruction of total organic solids. Sixty percent of this destruction is reported to occur in the first reactor.

A 2-reactor series configuration is used to provide a means of isolation of the digested (pasteurized) sludge from contamination by incoming raw sludge. Batch feeding of the system is established by design intent and is reflected in the size of the sludge feed pump which is sized to deliver the daily sludge volume to the ATAD system within a short (<1 hour) time period.

The aeration devices used are aspirator type aerators. A typical installation utilizes two side mounted aerators (one center floating aerator may be included dependent upon the reactor sizing) that are easily removed for maintenance. Relatively high oxygen transfer efficiencies, in the range of 1.5 to 3.7 Kg O₂/kwh (2.5-6.1 lb O₂/hp/hr), are reported by the manufacturer. It is also indicated that the aerator efficiency increases as the solids concentration in the reactor increases. An average of 2.1 Kg O₂/kwh (3.5 lb O₂/hp/hr) is used for design purposes.

A rotary blade type foam cutter is utilized (usually 2 per reactor) to limit the buildup of foam in the reactor.

A 20-day (minimum) storage capacity is recommended for the treated (digested) sludge. Aside from storage requirements related to variations in disposal rates, a 20-day period is recommended to allow adequate cooling of the sludge before post thickening or dewatering. The settling (and possibly dewatering) characteristics are reported to be greatly improved if the sludge is allowed to cool to 20°C. Some Fuchs facilities utilize heat exchangers to recover excess heat for building heat. This is an optional consideration.

o Thieme

Design information that was available regarding the Thieme ATAD system is summarized in Table 1. A typical Thieme system is depicted in Figure 2.

On comparison, the Thieme process is very similar to the Fuchs ATAD system. A significant difference between the systems is that the Thieme system prethickens sludge to a concentration of 10 to 12 percent using a rotary screen. The increased feed solids concentration has permitted the manufacturer to reduce the digestion reactors to approximately 30 percent of the volume used in the Fuchs system.

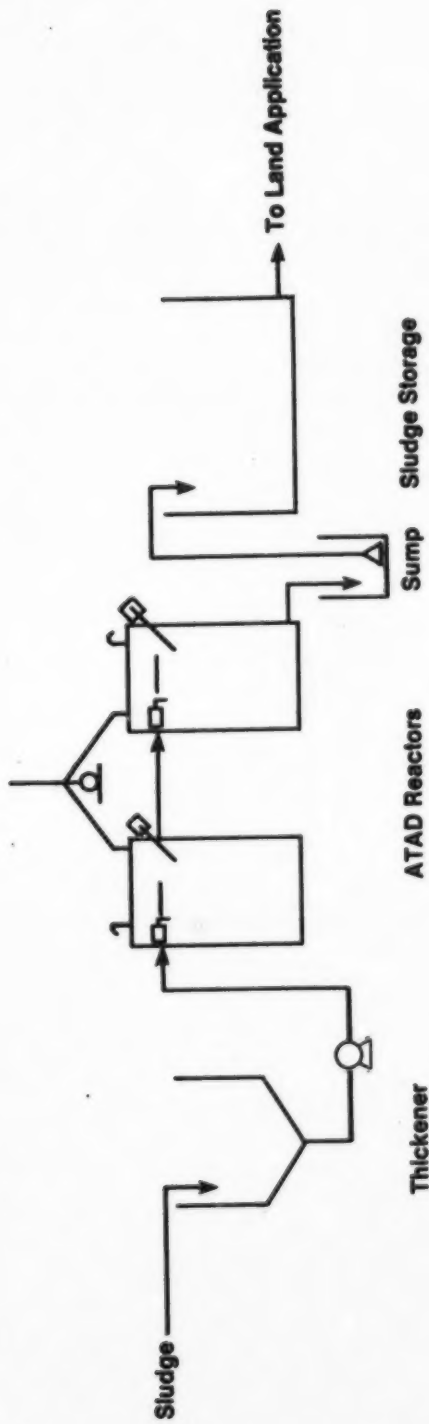


FIGURE 2A FUCHS ATAD SYSTEM

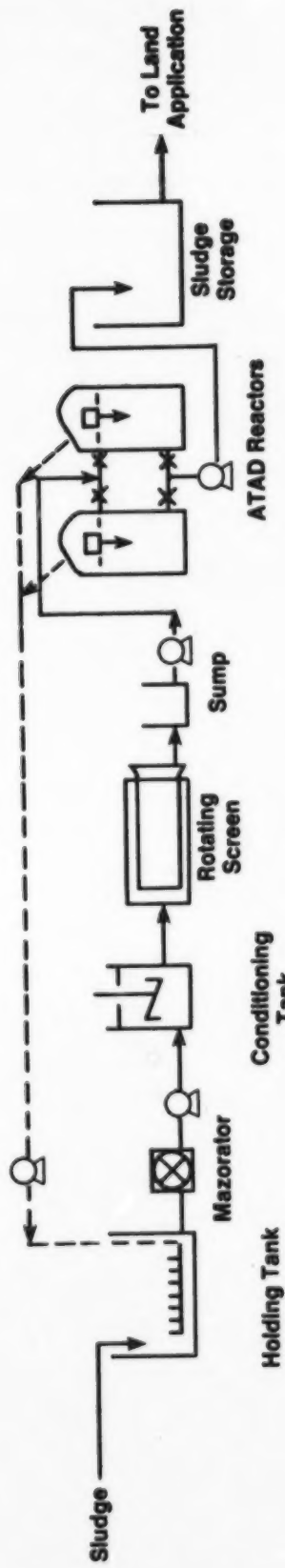


FIGURE 2B THIEME ATAD SYSTEM

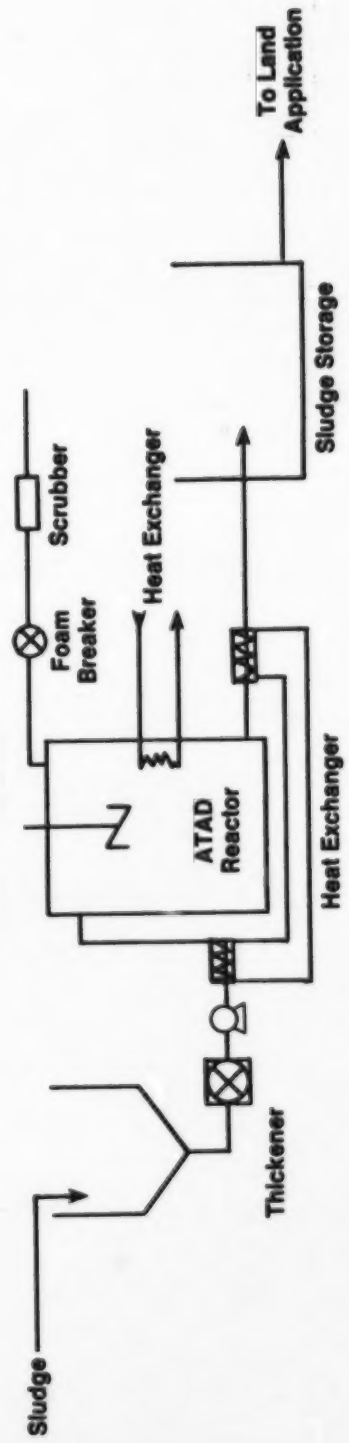


FIGURE 2C BABOCK ATAD SYSTEM

The hydraulic detention time, number of reactors, series operation, and batch feed strategy are all similar to Fuchs ATAD system.

Aeration and mixing requirements have not yet been defined by the manufacturer (some limited operating information is available). An aspirator type aerator is used which is similar in concept, but vastly different in mechanical design from the Fuchs aerators.

o Babcock

A typical Babcock ATAD system is illustrated in Figure 2.

This variation of the ATAD process differs significantly from the Fuchs and Thieme systems in that a single reactor is used and a continuous or semi-continuous sludge feeding method is utilized. Additionally, a different type of aeration system (submerged turbine) is installed in the Babcock ATAD system.

The hydraulic detention time and aeration power requirements are similar to the Fuchs ATAD system.

A heat exchanger is used as an economizer to extract heat from the effluent sludge which is in turn used to preheat the influent sludge. Additionally, a heat exchanger is used to extract excess heat from the process to be utilized elsewhere (i.e., typically for building heat). No information is available from the manufacturer to indicate if the economizer is required for process reasons to preheat the influent sludge. It is assumed that the heat extraction heat exchanger is optional as it is for the Fuch's system.

OPERABILITY AND PERFORMANCE

Table 2 represents a summary of the operating status of 6 ATAD facilities that were reviewed in the FRG. Operability and performance criteria assessed during the review of these facilities are discussed below.

o General

A common factor identified in all six ATAD facilities is that the process is easy to operate. In all cases, very little process control and maintenance is required. Normally, process control consists of performing periodic suspended solids analyses, monitoring reactor temperatures, and controlling the pumping of specific volumes of sludge to the ATAD reactors on a batch basis. Several of the operating facilities reported that less than 1 hour per day was required to operate and maintain the system. The simplicity of the operation implies that most of the process constraints are considered during the design phase thus minimizing required operator attention.

o Pathogen Destruction

The ATAD process in FRG is required to meet a limitation of 100 enterobacteria/ml in the final sludge product as mandated by regulations in the FRG¹⁹. This limitation is consistent with FRG regulatory requirements to become fully effective in 1987. The ATAD process in the FRG now maintains a status of approval by the Federal government as a process that is capable of producing a pasteurized (hygienic) sludge. This status is similar to the designation in the U.S. as a Process to Further Reduce Pathogens.²⁰

The treatment facilities that utilize the ATAD process are sampled twice per year by the regional health district. These samples are analyzed for a number of parameters

Table 2

Summary of ATAD Actual Operating Conditions

Parameter	Facility					
	I	F	N	G	V	S
No. of Reactors	2	2	2	2	2	1
Dimensions, $\varnothing \times H$, m	5 x 3	7.0 x 3.5	7.5 x 4	3.5 x 2.5	6.5 x 2.25	7 x 2.5
Volume ¹ (Occupied by Sludge) Total, m ³	120	120	360	48	150	96
Sludge Influent Flow, m ³ /day	9	20	70	8	15	5
Sludge Concentration, TSS/TVSS, percent	4/3.1	4/3.4	5.5/3.6	5/3.0	3.5/2.8	6/3.6
Sludge Mass Loading, TVSS, kg/day	280	680	2,520	240	420	180
Sludge TVSS Loading Rate, kg/day/m ³	2.3	5.7	7.0	5.0	2.8	1.8
Reactor(s) Detention Time, days	13 ³ (6.6) ⁴	12 (6)	5.1	6.0	10	19.2
Aeration Installed Power, kw	8.8	9.5	38	4.4	11.8	5.5
Aeration Power Consumption ² , kwh/day	211	228	912	106	284	132
Aeration Power/Sludge Volume, kwh/m ³ /day	23.4 (12.0) ⁴	22.8 (12.6) ⁴	13.0	13.3	18.9	26.4
Aeration Power/Reactor Volume, W/m ³	73	79	106	92	79	57
Aeration Power/Sludge Mass, TVSS, kwh/kg	0.75	0.74	0.36	0.44	0.68	0.73

Notes

1. Tank volumes refer to operating volume with sludge. Additional tank volume is installed in varying amounts for freeboard.
2. Power consumption is calculated on a 24-hr basis; actual operation $\approx$ 23.5 hr/day.
3. Since July 1984 (after the field visit), Isenbüttel and Fassberg were operated as a one-stage operation with batch feeding 3 to 4 times/week to maintain pasteurization.
4. When operated in single stage.

I = Isenbüttel

F = Fassberg

N = Nettetal-Viersen

G = Gemmingen

V = Vilsbiburg

S = Schöntal (not considered to be an actual ATAD facility)

including coliform count. If the sludge is determined to meet the above limitation of 100 #/ml (in addition to meeting other organic and inorganic criteria), it is approved as being "acceptable" for agricultural utilization.

Pasteurization by definition requires the attainment of a temperature equal to or exceeding 70°C, and the maintenance of that temperature for a 30-minute time period. The ATAD process does not typically operate at 70°C; however, it attains temperatures of 55-65°C and maintains these temperatures over a longer period of time. The pathogen destruction achieved, therefore, is reported¹⁶ to be comparable to the pathogen destruction from a "pasteurization" process based on the 100 enterobacteria/ml limitation. The process has been shown capable of destroying salmonella, parasite eggs and viruses provided a temperature of 50°C is maintained for 57 hours of aeration time (Strauch,²¹ Bohm et al.,²²).

The ATAD operating strategy maximizes the pathogen destruction potential of the process and minimizes the chance for contamination. In order to prevent contamination with raw incoming sludge, a specific volume of sludge is removed on a daily basis from the second stage reactor (which is operating in a range of 55-65°C). Once the sludge is removed, sludge from the first stage reactor is transferred into it as a batch. The second stage is then not disturbed until the next batch is loaded 24 hours later. With this operating method, sludge that has been transferred over from the first stage reactor is maintained at a thermophilic temperature for a minimum period of 24 hours. Raw sludge is then fed into the first stage to make up the volume that was removed when sludge was transferred. This stepwise feeding approach isolates the sludge reactors from each other and minimizes the potential for contamination of the final sludge product.

o Temperature

Table 3 summarizes reactor temperatures determined during field visits and review of operating data.

Of particular concern for meso- and thermophilic- systems is the impact that batch feeding may have on the reactor temperature. Some concern has been expressed by researchers in the field that batch feeding of the digestion reactor may suppress the reactor temperature significantly, resulting in a loss of digestion and pathogen destruction efficiencies.

This potential was considered when the ATAD facilities were visited in Germany. It was observed that, during the batch feeding into Reactor No. 1, the temperature was depressed by approximately 5 to 6°C. However, the reactor recovered at a rate of 1°C per hour, resulting in a complete temperature recovery in 5 to 6 hours after the initial feeding. The temperature depression in Reactor No. 2 was somewhat less on the order of 3 to 4°C and recovered at a similar rate as was observed in Reactor No. 1.

The observed temperature pattern is similar to those illustrated in Figure 3 which is based on research findings at Gemmingen.¹⁶

o Feed Solids

Operational guidelines for the feed sludge concentration to the ATAD process are typically specified in the ATAD plants designed by Fuchs. Operating personnel maintain the feed sludge concentrations within a range of 3 to 5 percent. It was indicated that below 3 percent solids concentration, the temperature drop in Reactor No. 1 is excessive and that above 5 percent solids, excessive foaming may occur in Reactor No. 2.

Table 3

Summary of Reactor Temperatures

Facility	Influent Sludge Temperature (°C)	Reactor No. 1 (°C)	Reactor No. 2 (°C)
Vilsbiburg	12 - 18	60	69
Gemmingen	6 - 14	30 - 50	50 - 60
Nettetal-Viersen	10 - 22	38	58
Fassberg	6 - 15	40 - 45	50 - 70
Shöntal*	---	---	---
Isenbüttel	8 - 20	40 - 55	45 - 60
Rheinhausen	---	42**	60**

*Not considered an ATAD facility due to open tank design.
Intended to be retrofitted into an ATAD system by addition
of a tank cover.

**Arithmetic mean of temperature measurements taken during 14
weeks.

- o Volatile Solids Reduction

Volatile solids reduction is reported to be ≥ 40 percent for the ATAD system. Figure 3 illustrates the volatile solids reduction achieved at the Gemmingen facility¹⁶. Volatile solids reductions of 40 percent were achieved as the detention time became greater than four days.

None of the operating facilities routinely perform TVSS analyses of the influent and effluent sludge streams for the ATAD systems. However, a limited amount of data are available from Health District analyses. A review of the Health District analyses and facility data indicates that the TVS reduction ranged from 44 to 41 percent for one of the typical Fuchs facilities reviewed (Nettetal- Viersen). Volatile solids reduction for the Thieme ATAD system in Rheinhausen averaged 44 percent over a 14 week period.

o Odor

Of the six facilities reviewed, none exhibited offensive odors during the visits. Discharges from the ATAD reactors could be characterized as "musty" and very similar to odors experienced from conventional aerobic digesters. Three facilities reported occasional odors. One of these facilities reported occasional odors when the reactor temperature exceeds 65°C, while the other two experienced some odor only when raw sludge was pumped to the system.

Two of the facilities in close proximity to residential areas are equipped with exhaust gas scrubbers for the ATAD reactors. The application of these scrubbers is considered to be somewhat experimental. Performance is reported to be good; however, occasional odors have been noted even with the scrubbers in place.

- o **Sludge Dewaterability**

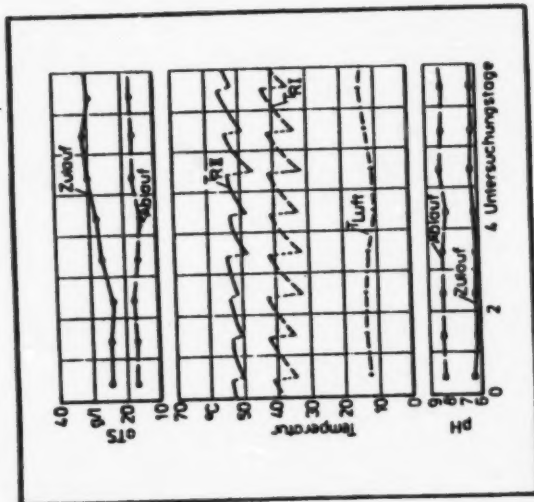
Dewatering trials were conducted at the Vilsbiburg ATAD facility using a belt press and decanter centrifuges. Preliminary (unpublished) results for centrifugation and belt filtration include the following:

- ATAD Reactor Effluent; TS = 2.5 percent
influent to dewatering
- Sludge Cake; TS = 30 to 35 percent
- Polymer Dose; 4 to 6 g of polymer/kg of
sludge
- Feed Temperature; 48 to 63°C

These results indicate acceptable dewatering performance. Indeed, for centrifugation, exceptionally high cake solids are experienced. It has been hypothesized that the high cake solids achieved may be due to reduced sludge viscosity at higher temperatures. It was also reported that the centrifuge centrate was dirtier than would normally be expected for a mesophilically-digested sludge.

COST

Capital cost data were provided by manufacturers and facility engineers for eight ATAD installations. These cost data were limited to the system components which the manufacturers supplied. This information was utilized along with separate cost



Legend

- OTS = Organic total solids
- Zulauf = Influent
- Ablauf = Effluent
- TR II = Reactor No. 2 Temperature
- TR I = Reactor No. 1 Temperature
- TLUFT = Air Temperature

FIGURE 3 GEMMINGEN DATA 17

estimates for processes not included in the manufacturers' cost information to estimate the capital cost of a complete ATAD system of: 1) prethickening to 3-5% TS, 2) ATAD system with 6 days hydraulic detention time, 3) 20 days post storage, 4) pumping system, and 5) concrete slab for tankage. All costs were adjusted to US dollars; March 1984.

These costs are compared in Figure 4 to capital cost estimates for aerobic and anaerobic digestion systems with similar sludge throughput capacities as those observed for the ATAD systems. Conventional aerobic and anaerobic digestion system cost estimates were developed from a U.S. cost source²³ which was similarly adjusted to the March 1984 cost base. For estimating purposes, aerobic digestion costs include pre and post thickening while anaerobic digestion costs only include pre-thickening (post-thickening is assumed to occur in the second stage of the anaerobic digestion system). Prethickening to 3-5% solids was assumed for both aerobic and anaerobic digestion systems with hydraulic detention times of 20 and 12.5 days (first stage), respectively.

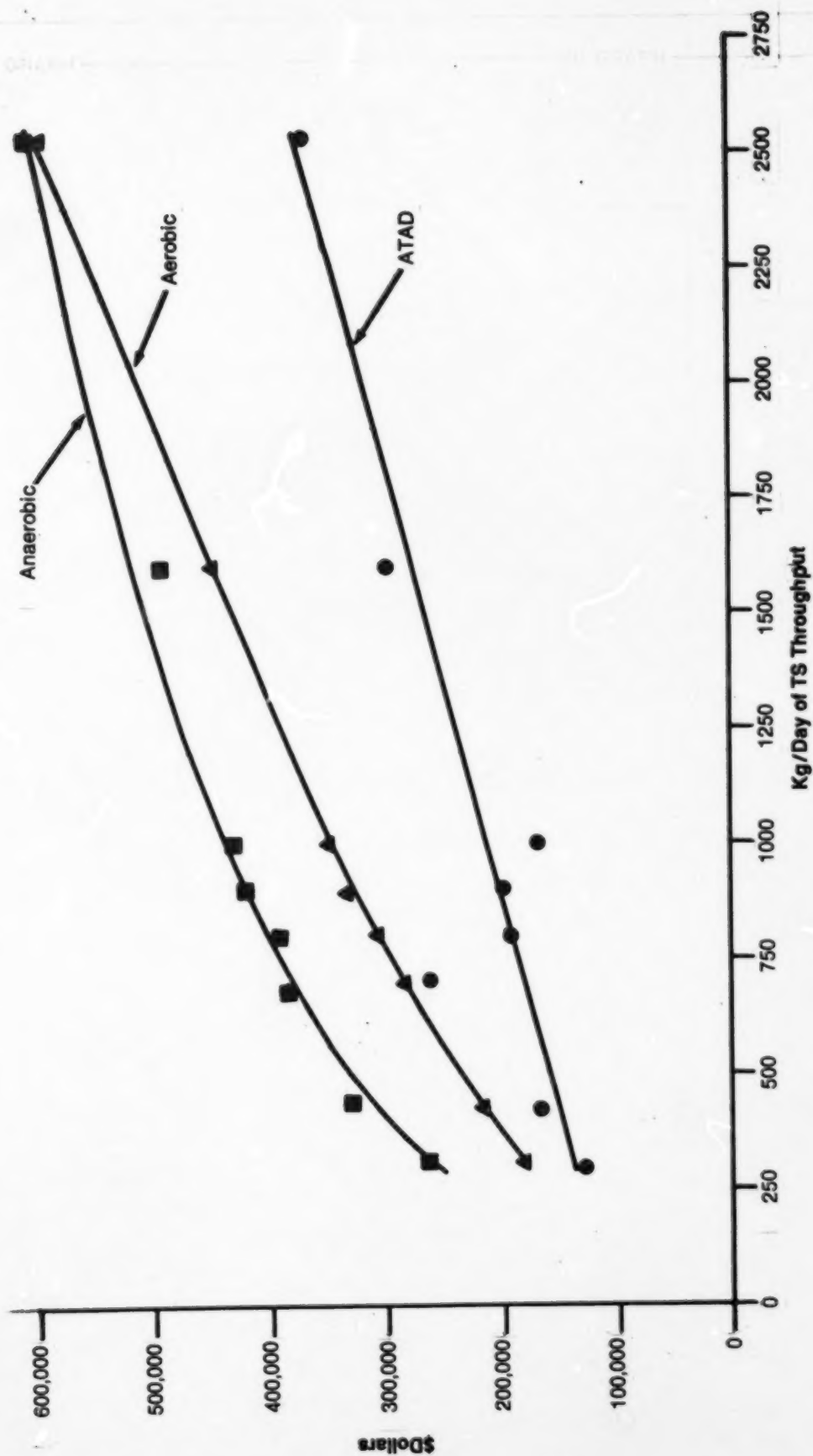
CONCLUSION

All of the people with whom this process was discussed, and who had direct knowledge of the system operation in FRG, indicated that the ATAD system was operated with relative ease. These comments were made by plant operating personnel, design engineers, and by the manufacturer's representative. The on-site review of the ATAD system operation confirmed this view.

The process performance factors were generally found to be acceptable. These included: volatile solids reductions >40 percent, thermophilic (>43°C) temperature conditions in the second stage reactor, apparent pathogen reduction equivalent to a Process to Further Reduce Pathogens, and infrequent incidence of odors.

Additionally, cost analyses performed in the FRG have indicated that the ATAD system is the most cost effective alternative for sludge digestion (compared to conventional aerobic and anaerobic digestion) for facilities of small to medium size (<4MGD).²⁴ The cost comparison made as a result of this recent ATAD assessment indicates that this relationship may hold true for the U.S. as well. It is important to note that no consideration was given to the benefit of achieving "pasteurization" of the sludge during cost comparisons performed in the FRG or in the U.S. Typically, an additional process (i.e., gamma irradiation) may be required to achieve similar levels of sludge quality. This benefit may significantly increase the apparent cost benefits of the ATAD process.

FIGURE 4 COMPARATIVE DIGESTION CAPITAL COSTS



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